KEY CONCEPT

2.2 Cells capture and release energy.

BEFORE, you learned

- The cell is the basic unit of all living things
- Plant cells and animal cells have similarities and differences
- Plants and animals need energy and materials

NOW, you will learn

- Why cells need energy
- How energy is captured and stored
- How plants and animals get energy

VOCABULARY

chemical energy p. 47
glucose p. 47
photosynthesis p. 48
chlorophyll p. 48
cellular respiration p. 50
fermentation p. 52

THINK ABOUT

What do these cells have in common?

Both muscle cells and plant cells need energy to live. Your muscle cells need energy to help you move and perform other functions. Even though plant cells don't move in the same way that muscles move, they still need energy. How do human muscle cells and plant cells get energy?

OUTLINE
Remember to include this heading in your outline of this section.

I. Main idea
  A. Supporting idea
    1. Detail
    2. Detail
  B. Supporting idea

All cells need energy.

To stay alive, cells need a constant supply of energy. Animal cells get energy from food, while plant cells get energy from sunlight. All cells use chemical energy. **Chemical energy** is the energy stored in the bonds between atoms of every molecule. To stay alive, cells must be able to release the chemical energy in the bonds.

A major energy source for most cells is stored in a sugar molecule called **glucose.** When you need energy, cells release chemical energy from glucose. You need food energy to run, walk, and even during sleep. Your cells use energy from food to carry out all of their activities.

Think about muscle cells. When you run, muscle cells release chemical energy from glucose to move your legs. The more you run, the more glucose your muscle cells need. You eat food to restore the glucose supply in muscles. But how do plant cells get more glucose? Plants transform the energy in sunlight into the chemical energy in glucose.

Some cells capture light energy.

The source of energy for almost all organisms ultimately comes from sunlight. Plants change the energy in sunlight into a form of energy their cells can use—the chemical energy in glucose. All animals benefit from the ability of plants to convert sunlight to food energy. Animals either eat plants, or they eat other animals that have eaten plants.

Photosynthesis (FOH-toh-SIHN-thih-sihs) is the process that plant cells use to change the energy from sunlight into chemical energy. Photosynthesis takes place in plant cells that have chloroplasts. Chloroplasts contain **chlorophyll** (KLAWR-uh-fihl), a light-absorbing pigment, or colored substance, that traps the energy in sunlight.

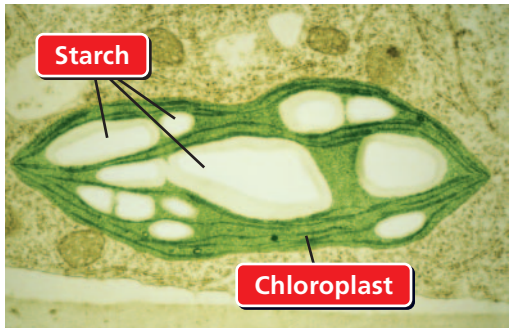
The process of photosynthesis involves a series of chemical steps, or reactions. The illustration on the next page shows an overview of how photosynthesis changes starting materials into new products.

READING TiP
As you read each numbered item here, find the number on the diagram on page 49.

1. **The starting materials** of photosynthesis are carbon dioxide and water. The plant takes in carbon dioxide from the air and water from the soil.
2. **The process** takes place when carbon dioxide and water enter the plant's chloroplasts. Chlorophyll captures energy from sunlight, which is used to change carbon dioxide and water into new products.
3. **The products** of photosynthesis are oxygen and sugars such as glucose. The plant releases most of the oxygen to the air as a waste product and keeps the glucose for its energy needs.

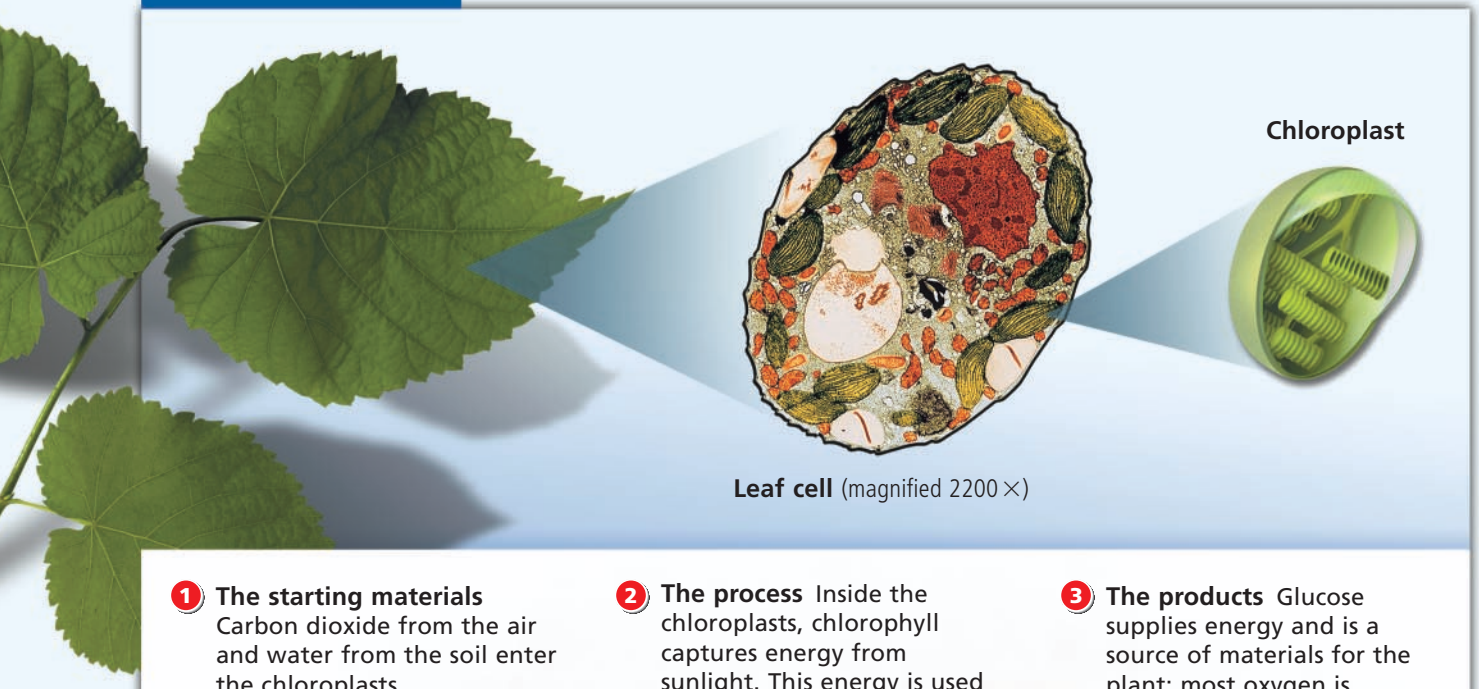
CHECK YOUR READING
Summarize photosynthesis. Remember that a summary includes only the most important information.

Plants do not immediately use all of the glucose they make. Some of the glucose molecules are linked together to build large carbohydrates called starch. Plants can store starch and later break it back down into glucose or other sugars when they need energy. Sugars and starches supply food for animals that eat plants.



The starch in this plant cell stores energy.

Photosynthesis

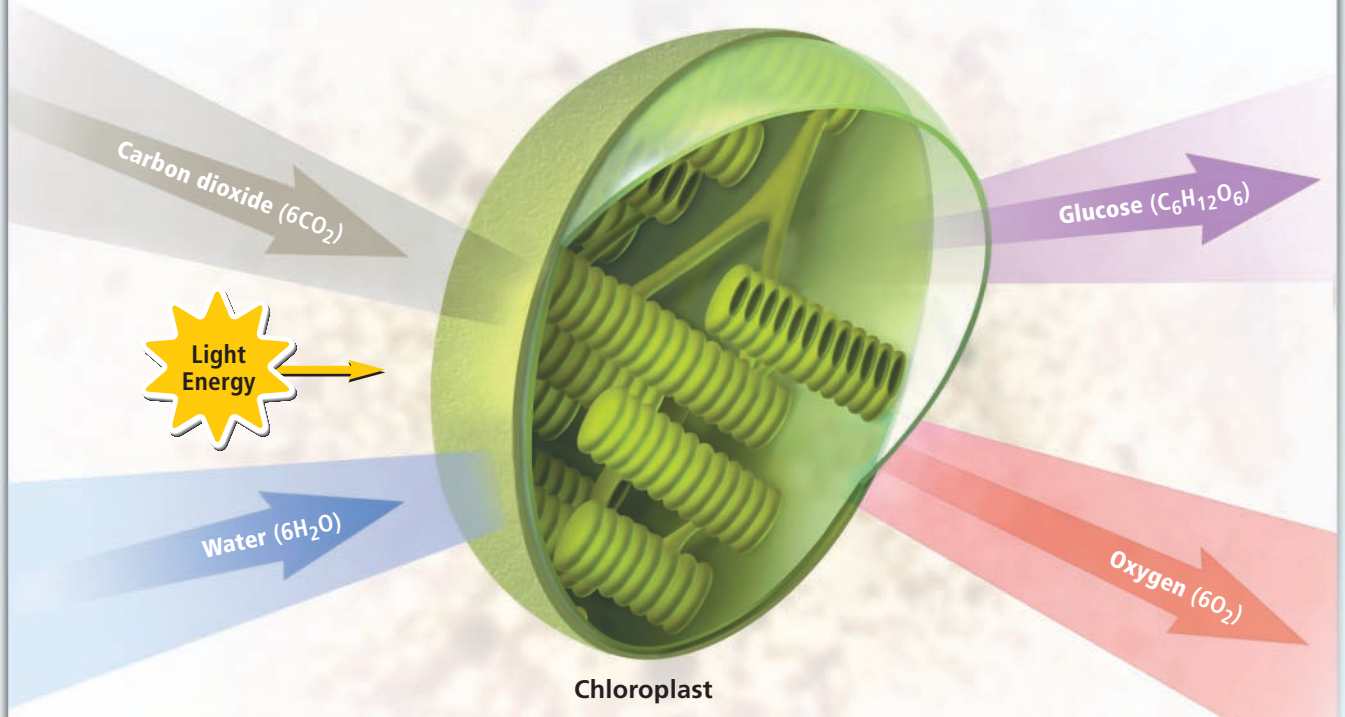


Leaf cell (magnified 2200×)

1 The starting materials Carbon dioxide from the air and water from the soil enter the chloroplasts.

2 The process Inside the chloroplasts, chlorophyll captures energy from sunlight. This energy is used to change starting materials into new products.

3 The products Glucose supplies energy and is a source of materials for the plant; most oxygen is released into the air.



Chloroplast

Water $6H_2O$	+	Carbon dioxide $6CO_2$	+	Light Energy	→	Glucose $C_6H_{12}O_6$	+	Oxygen $6O_2$

READING VISUALS What part of the diagram shows starting materials being changed?

All cells release energy.

All cells must have energy to function. Glucose and other sugars are cell food—they are the power source for cell activities in almost all living things. When glucose is stored as glycogen or taken in as starch, it must be broken down into individual sugar molecules before cells are able to use it. Chemical energy is stored in the bonds of sugars. When a sugar molecule is broken down, a usable form of energy is released for the cell's life functions.

Cells can release energy in two basic processes: cellular respiration and fermentation. Cellular respiration requires oxygen, but fermentation does not. In addition, cellular respiration releases much more usable energy than does fermentation.

CHECK YOUR READING What is released when a sugar molecule is broken down?

Cellular Respiration

In **cellular respiration,** cells use oxygen to release energy stored in sugars such as glucose. In fact, most of the energy used by the cells in your body is provided by cellular respiration.

Just as photosynthesis occurs in organelles called chloroplasts, cellular respiration takes place in organelles called mitochondria. Remember that mitochondria are in both plant cells and animal cells, so both kinds of cells release energy through cellular respiration.

Like photosynthesis, cellular respiration is a process that changes starting materials into new products.

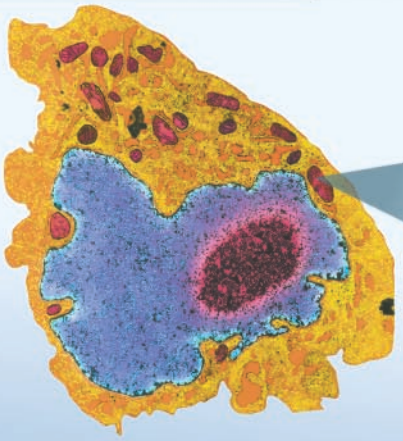
1. **The starting materials** of cellular respiration are sugars—such as glucose—and oxygen.
2. **The process** begins when glucose in the cytoplasm is broken down into smaller molecules. This releases a small amount of energy. These molecules then move into the mitochondria. At the same time, oxygen enters the cell and travels into the mitochondria. As the smaller molecules are broken down even further, hydrogen is released in a way that allows cells to capture energy in a usable form. The hydrogen combines with oxygen to make water.
3. **The products** are energy, carbon dioxide, and water.

READING TiP
Reread step 2 to make sure you understand what happens to oxygen and glucose.

Some of the energy released during cellular respiration is transferred to other molecules, which then carry the energy where it is needed for the activities of the cell. The rest of the energy is released as heat. Carbon dioxide formed during cellular respiration is released by the cell.

CHECK YOUR READING What are the three products of cellular respiration?

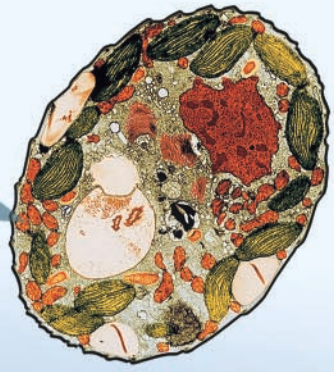
Cellular Respiration



Animal cell
(magnified 2400×)

Mitochondrion

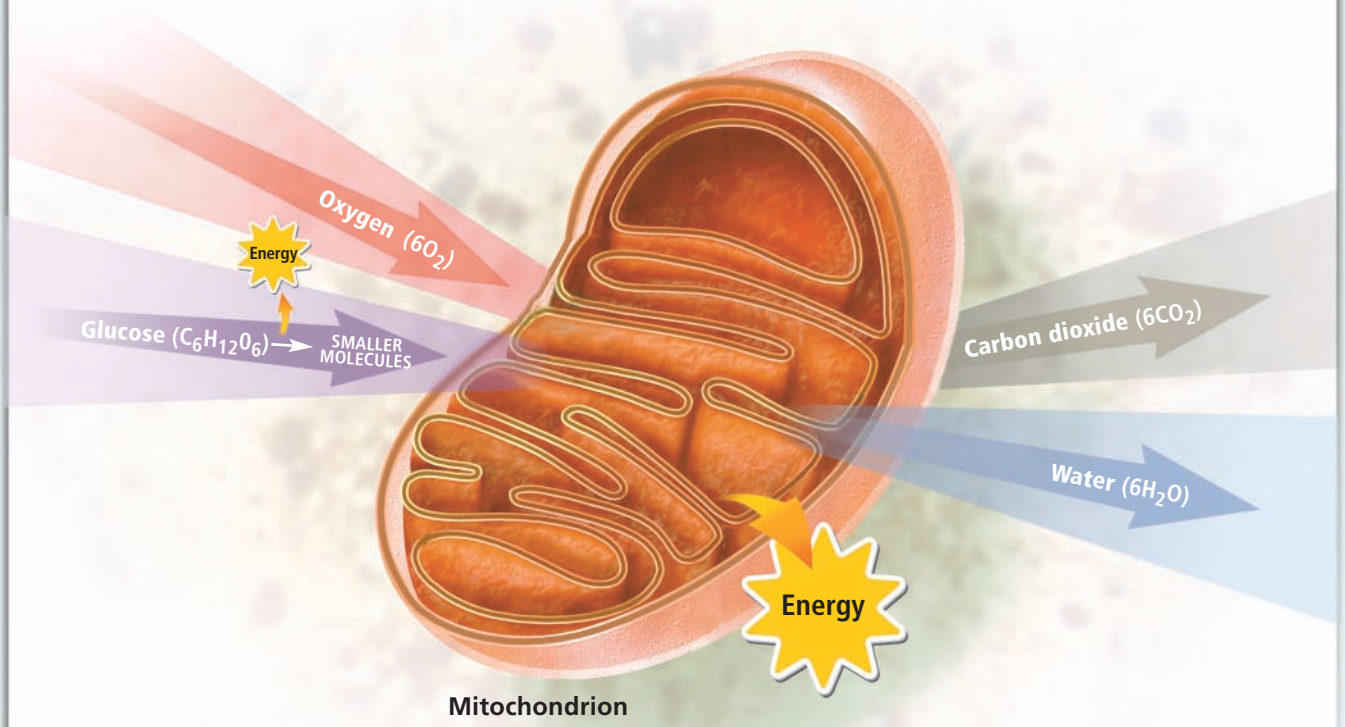
Leaf cell (magnified 2200×)



1 The starting materials Glucose and oxygen enter the cell. Glucose is split into smaller molecules.

2 The process Inside the mitochondria more chemical bonds are broken in the smaller molecules. Oxygen is needed for this process.

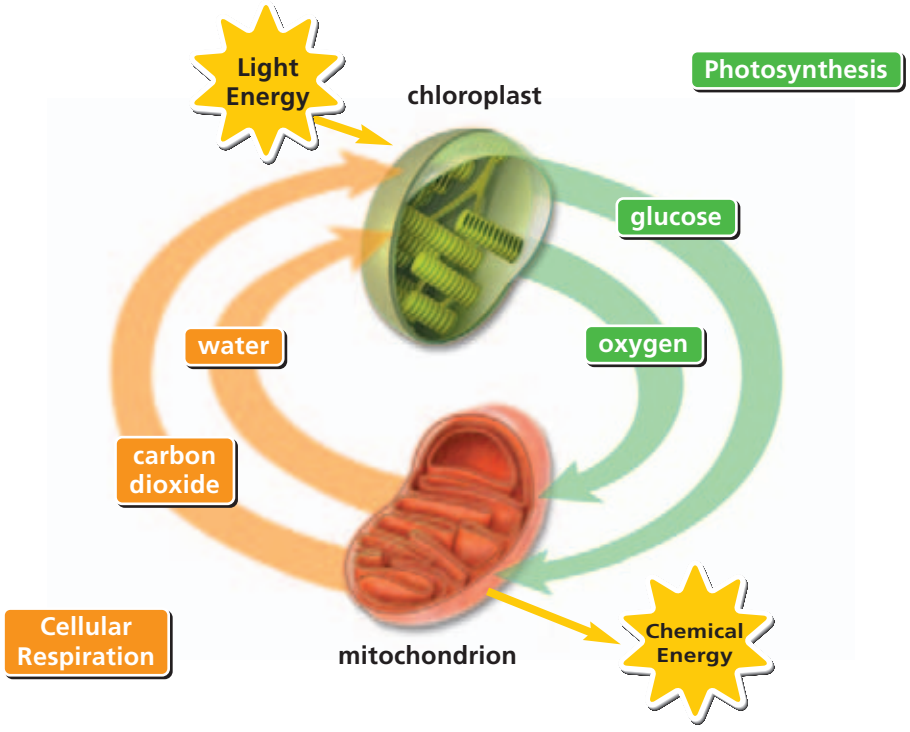
3 The products Energy is released, and water and carbon dioxide are produced.



Glucose $C_6H_{12}O_6$	+	Oxygen $6O_2$	→	Chemical Energy	+	Water $6H_2O$	+	Carbon dioxide $6CO_2$

READING VISUALS Where in the process is energy released?

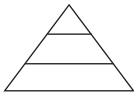
Photosynthesis and Respiration Cycle



You may find it interesting to compare cellular respiration with photosynthesis. The diagram above highlights the cycle that occurs between photosynthesis and cellular respiration. Notice that the starting materials of one process are also the products of the other process. This cycle does not necessarily occur in the same cell, or even in the same organism.

Fermentation

VOCABULARY
Add a word triangle for *fermentation* to your notebook. Your triangle could include a sketch of a loaf of bread.



Fermentation is the process by which cells release energy without oxygen. Recall that in cellular respiration the cell first breaks glucose into smaller molecules. This releases a small amount of energy. Without oxygen, cellular respiration cannot continue. In eukaryotic cells, instead of entering the mitochondria, these smaller molecules stay in the cytoplasm, where fermentation occurs.

There are two main types of fermentation: alcoholic fermentation and lactic acid fermentation. Both types of fermentation break sugars down to small molecules. In the absence of oxygen, different reactions occur that produce either alcohol and carbon dioxide or lactic acid. In both cases, a small amount of energy is released.

CHECK YOUR READING Use a Venn diagram to compare and contrast fermentation and cellular respiration.

The production of many foods that people eat every day involve either alcoholic fermentation or lactic acid fermentation. Three important foods are bread, yogurt, and cheese.

Bread is often made by mixing flour, milk, and sugar with a microorganism you know as yeast. Yeast runs out of oxygen and uses fermentation to convert the sugar into alcohol and carbon dioxide. Bubbles of carbon dioxide gas forming inside the dough cause it to rise. When the dough is baked, the small amount of alcohol evaporates, the yeast is killed, and the carbon dioxide bubbles give the bread a light, spongy structure.

Some bacteria release energy through lactic acid fermentation. These bacteria convert the sugar found in milk into lactic acid and are used to make yogurt, cheese, and sourdough bread. Lactic acid changes the acidity of a bread mixture to give it a slightly sour flavor. In yogurt and cheese, the buildup of lactic acid causes the milk to partially solidify, producing the creamy texture of yogurt. If fermentation continues for a long time, the milk eventually turns into cheese.

INVESTIGATE Fermentation

How can you tell if fermentation releases material?

SKILL FOCUS
Observing

MATERIALS
- dry yeast
- spoon
- small water bottle
- warm sugar solution
- balloon

TIME
30 minutes

PROCEDURE

1. Add 1/2 teaspoon of yeast to the empty water bottle.
2. Fill the bottle about three-quarters full with the sugar solution.
3. Place the balloon tightly around the mouth of the bottle.
4. Gently swirl the bottle to mix the yeast and sugar solution.
5. After 20 minutes, observe the balloon and record your observations.

WHAT DO YOU THINK?

- What changes did you observe? What do you think is the source of energy that caused these changes?
- What accounts for the change in the amount of gas inside the balloon?

CHALLENGE Design an experiment to answer the following question. How might the temperature of the sugar solution affect the process?

Energy and Exercise

Your muscle cells, like some organisms, are able to release energy by both cellular respiration and fermentation. While you are at rest, your muscle cells use specialized molecules to store both energy and oxygen.

During hard or prolonged exercise, your muscle cells may use up all their stores of energy and oxygen. Then your muscle cells rely on fermentation to break down sugars. There is much less energy available to cells that use fermentation, which is why you cannot continue to run rapidly for long distances. When your cells use fermentation to release energy, one of the waste products is lactic acid, which can cause a burning sensation in your muscles.

APPLY Why might these students feel a burning sensation in their arm muscles while doing pull-ups?

When you stop after this type of exercise, your muscles continue to hurt and you continue to breathe hard for many minutes. During this time, your muscles are playing catch-up. They use the oxygen brought into your blood by your heavy breathing to finish breaking down the byproducts of fermentation. As the lactic acid is converted into carbon dioxide and water, the burning sensation in your muscles goes away. Your muscles build back up their stores of energy and oxygen until the next time they are needed.

2.2 Review

KEY CONCEPTS

1. Which form of energy is especially important for living things? Why?
2. How is photosynthesis important to life on Earth?
3. What starting materials do cells need for cellular respiration?

CRITICAL THINKING

4. **Compare and Contrast** How are photosynthesis and cellular respiration similar? How are they different?
5. **Predict** Suppose that in a lab you could remove all the oxygen from a terrarium. What would happen to the plants? Why?

CHALLENGE

6. **Synthesize** In everyday language, the word *respiration* refers to breathing. How is breathing related to *cellular respiration*? **Hint: The air we breathe out contains more carbon dioxide than the air we breathe in.**